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Bryophytes: Source of Herbal Remedies and Antibiotic Production

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ABSTRACT

The Bryophyta are a proposed taxonomic division containing three groups of non-vascular land plants (embryophytes): the liverworts, hornworts and mosses. Bryophyta s.s. consists of the mosses only. They are characteristically limited in size and prefer moist habitats although they can survive in drier environments. The bryophytes consist of about 20,000 plant species. Bryophytes produce enclosed reproductive structures (gametangia and sporangia), but they do not produce flowers or seeds. They reproduce sexually by spores and asexually by fragmentation or the production of gemmae. Though bryophytes were considered a paraphyletic group in recent years, almost all of the most recent phylogenetic evidence supports the monophyly of this group, as originally classified by Wilhelm Schimper in 1879. Bryophytes are popular remedy among the tribal people of different parts of the world. Tribal people use these plants to cure various ailments in their daily lives. Bryophytes are used to cure hepatic disorders, skin diseases, cardiovascular diseases, used as antipyretic, antimicrobial, wound healing and many more other ailments by different tribal communities of Africa, America, Europe, Poland, Argentina, Australia, New Zealand, Turkey, Japan, Taiwan, Pakistan, China, Nepal and different parts of South, North and Eastern India. Apart from ethno-medicinal uses some bryophytes possesses antitumor activities against different cancer cell lines and this property of bryophytes needs to be more focused in the future. Bryophytes display a plethora of medicinal properties and may be used to treat hepatic disorders, skin diseases, cardiovascular diseases, fever and wound. The phytochemicals isolated from them can be used to produce a range of novel pharmacologically active compounds.

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INTRODUCTION

It has been demonstrated that bryophytes contain a number of potentially useful natural products, such as lipids, phenylpropanoids, polysaccharides, quinones, rare amino acids, terpenoids, and many other specialized compounds. There have been reports of compounds isolated from bryophytes showing antimicrobial, antiviral, cytotoxic, neuroprotective, nematocidal and insecticidal effects. Besides, they have demonstrated their effects on smooth and non-striated muscles and weight loss, as plant growth regulators and allelopathic. In addition to causing allergies and skin reactions, bryophytes were also reported to cause contact dermatitis. Bryophytes display a plethora of medicinal properties and may be used to treat hepatic disorders, skin diseases, cardiovascular diseases, fever and wound. The phytochemicals isolated from them can be used to produce a range of novel pharmacologically active compounds.[1,2]

Bryophytes are the second largest group of land plants after angiosperms. There is very less knowledge available about medicinal properties of these plants. Bryophytes are popular remedy among the tribal people of different parts of the world. Tribal people use these plants to cure various ailments in their daily lives. Bryophytes are used to cure hepatic disorders, skin diseases, cardiovascular diseases, used as antipyretic, antimicrobial, wound healing and many more other ailments by different tribal communities of Africa, America, Europe, Poland, Argentina, Australia, New Zealand, Turkey, Japan, Taiwan, Pakistan, China, Nepal and different parts of South, North and Eastern India. Apart from ethno-

medicinal uses some bryophytes possesses antitumor activities against different cancer cell lines and this property of bryophytes needs to be more focused in the future. The tribals are found to use some common bryophytes as well as pteridophytes in their routine health care system to treat the diseases like cold, fever, skin diseases, mental disorders, abdominal & respiratory disorders and sexual problems. The most common use of bryophytes is for medicinal purposes. *Sphagnum, Marchantia* and *Polytrichum* are the most commonly reported genera to have ethnobotanical uses. [3,4]

The antimicrobial activity of aqueous and ethanolic extracts of 11 *Bryophyta* species and 9 *Marchantiophyta* species collected in Latvia was tested against *Staphylococcus aureus*, *Escherichia coli* and *Bacillus cereus*. The extract of *Lophocolea heterophylla* inhibited the growth of B. cereus, but none of the tested extracts inhibited the growth of *E. coli*. 70% of bryophyte species demonstrated certain activity in relation to *S. aureus*. In general, 73% of ethanolic extracts and 39% of aqueous extracts exhibited antibacterial activity against *S. aureus*. The highest degree of antibacterial activity against *S. aureus* was shown by the ethanolic extract of *Dicranum scoparium* and aqueous extracts of *Atrichum undulatum* and *Rhytidiadelphus squarrosus*. The bactericidal action was not ascertained. For the first time antimicrobial activity has been proved for three moss species—*Eurhynchium angustirete*, *Rhytidiadelphus squarrosus* and *Rhodobryum roseum*, and for two liverwort species *Frullania dilatata* and *Lophocolea heterophylla*.

Discussion

An ancient method of determining the medicinal properties of plants is the concept of Paracelsus "doctrine of signatures" which deals with similarity of plant body parts to shape and structure of organ in the human or animal body for which it is corrective. As per above philosophy, liverworts (e.g. *Marchantia polymorpha*) used to cure hepatic ailments. Similarly, moss like *Polytrichum commune*is useful in treatment of hair fall so called hair cup moss. In ancient time period women were used to apply on their hair for beautification and cosmetics. [5,6]

1. Antioxidant Properties:

Antioxidants are those substances which at low concentration significantly inhibit or delay the oxidation of substrate. Few of the bryophyte species have been studied in context to antioxidant activity. Recent study suggests that some of the liverworts and moss possesses strong anti-oxidative machinery which helps them to survive in the extreme climate and stress condition. Heavy metal, desiccation and ultraviolet radiation have been found to trigger an array of different enzymes in bryophytes. Some bryophyte species hyper accumulate metals and some were sequestering the toxic metals. The study conducted on antioxidant activity of the Antarctic mosses *Sanionia uncinata* (Hedw.) Loeske and *Polytrichastrum alpinum* (Hedw.) G.L. Sm. var. alpinum has indicated their potential to be used as antioxidants for medicinal and cosmetic purpose

2. Anticancer properties:

Alcoholic extract of *Polytrichum juniperum* exhibited inhibitory property against Sarcoma 37 implanted in CAF1 mice. Total no of 168 aqueous and 42 organic extracts of different bryophyte were evaluated for *in vitro* for anti-proliferative activity on different human gynecological cancer cell lines containing cervix epithelial adenocarcinoma, ovarian carcinoma, invasive ductal breast carcinoma cells using the 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide (MTT) assay. A total of 99 extract from 41 species exert ≥25% inhibition of proliferation of at least one of the cancer cells lines at 10µg/ml. More than one extract of Bryophytes like *Brachythecium rutabulum*, *Encalypta streptocarpa*, *Climacium dendroides*, *Neckera besseri*, *Pleurozium schreberi*, and *Pseudoleskeella nervosa*, shown anti-proliferative actvity, *Paraleucobryum longifolium was shown maximum activity*.[7,8]

The extract of *Lepidozia borneensis* was found to induce cytotoxicity against MCF-7 cell line with IC_{50} value of 47.33±7.37µg/mL. Mainly cell cycle arrest G_0/G_1 occur during 24 hours of treatment. 72 hours after treatment, the cells proportion in G_0/G_1 and G_2-M phases had decreased significantly. Apoptosis occurred during the first 24 hours and significantly increased to 30.8% after 72 hours of treatment. The compound ohioensinan isolated from *Polytrichum ohioense* shows cytotoxicity against 9PS murine leukaemia and MCF-7 human breast tumour cells. Benzonaphthoxanthenones and cinnamoyl bibenzyls derivatives isolated from ethanolic extract of *Polytrichum pallidisetum* can significantly impede the growth of RPMI-7951 melanoma and U-251glioblastoma multiforme.

3. Antibacterial activity:

The antibacterial activity of *Asterella angusta* (Steph.) was studied against the two-gram negative bacteria namely *Escherichia coli, Pseudomonas aeruginosa* and two gram-positive bacteria *Bacillus subtilis* and *Staphylococcus aureus*. The aqueous and alcoholic extract was tested against the four bacteria. The maximum antibacterial activity was observed in alcoholic (Ethanolic) extract against Banerjee and Sen (1979) also reported the antibacterial activity of

methanolic, Ethanolic, ether, acetone extracts of *Asterell angusta* against *Salmonella typhi, Vibrio cholera, Pseudomonas aeruginosa, Mycobacterium phlei* and *Sarcinalutea*.[9,10]

4. Antidiabetic:

Diabetes mellitus describes the metabolic disorder having heterogeneous etiologies which are characterized by chronic hyperglycaemia and abnormal of carbohydrate, protein and fat metabolism due to impaired in insulin secretion, resistant to insulin action, or both were studied that liver wort *Plagiochasmac ordatum* was shown *in vitro* anti-diabetic potential by *α-amylase* inhibition assay methods.

5. Antifungal activity:

It was found that in bioactivity-guided partition of an anti-fungal extract from the liver wort *Asterella angusta* afforded four bis(bibenzyl)s, asterelin A, asterelin B, 11-*O*-demethyl marchantin I, and dihydroptychantol A. All bis(bibenzyl)s exhibited moderate inhibitory effects against the common clinical pathogenic fungus, *Candida albicans*. Many of the bryophyte species like are also known to show antifungal property. In another study it was proved that liverwort, *M polymorpha*, *C conicum, W denudata, M himalayensis and F himalayensis* possess antifungal potential.[11,12]

6. Anti-snake venom:

In case of snake generally anti-venoms are use. Anti-venoms can neutralize toxins. though, there is extensive achievement of conventional treatment, it is still significant to search for other dissimilar venom inhibitors, either synthetic or natural, that could complement or substitute for the action of the traditional antivenom. Thus, in the management of snakebite, the study of herbal antidotes against snake venom is of considerable significance to society *Marcantia polymorpha* contain Marchantin A, which is helpful in management of snake bite.

Table: 1 Bryophytes and their Pharmacological Properties

Sl. No	Botanical name	Family	Properties
1	Riccardia Gray. sp.	Aneuraceae	anti-leukemic
2	*Plagiochasm aappendiculatum*	Aytoniaceae	Skin diseases
3	*Reboulia hemisphaerica*(L.)	Aytoniaceae	Blotches, haemostasis, external wounds, and bruises
4	*Conocephalumconicum* (L.)	Conocephalaceae	Antimicrobial, antifungal, antipyretic, antidote, cuts, inflammation, scalds, burns, fractures, snake bites, gallstones
5	Herbertus Gray. sp.	Herbertaceae	Antiseptics, anti-diarrheal, expectorants and astringents
6	*Frullania tamarisci* (L.)	Jubulaceae	Antiseptic
7	*Frullania ericoides*	Jubulaceae	head lice (*Pediculus humanus*), nourish hair
8	*Marchantia polymorpha* L.	Marchantiaceae	inflammation, diuretics, liver ailments, insect bites, cuts, fractures, snake bites,
9	*Marchantia convoluta*	Marchantiaceae	Hepatitis, fever and gastric intolerance
10	*Marchanti apalmata*	Marchantiaceae	Acute inflammation
11	*Marchanti apaleacea*	Marchantiaceae	Skin tumefaction, hepatitis, antipyretic
12	*Dumortier ahirsuta*	Marchantiaceae	Antibiotics
13	*Pallavicinia*	Pallaviciniaceae	Antimicrobial agent
14	Plagiochila	Plagiochilaceae	Anti-leukemic, anti-microbial, perfumes
15	*Plagiochilabeddomei* Steph.	Plagiochilaceae	Wound healing
16	Riccia L. sp.	Ricciaceae	Thallus part is for ringworms in children.
17	*Targionia hypophylla* L.	Targioniaceae	With leaves of *Actiniopteris radiata* for scabies of children
Mosses			
18	Cratoneuronfilicinum	Amblystegiaceae	Heart disorders
19	*Leptodictyumriparium*	Amblystegiaceae	Antipyretic and uropathy
20	*Philonotis fontana*	Bartramiaceae	Burn pain, adenopharyngitis, antipyretic
21	*Philonotis Bridel* sp.	Bartramiaceae	burns, adenopharyngitis, antipyretic and antidote
22	*Plagiopusoederi*	Bartramiaceae	Sedative, epilepsy

23	*Bryum argenteum*	Bryaceae	Antidote, antipyretic, antifungal
24	*Rhodobryum giganteum*	Bryaceae	angina, anti-hypoxic, diuretic, antipyretic, and antihypertensive
25	*Rhodobryum roseum*	Bryaceae	cardiovascular diseases and sedative
26	*Leucobryum bowringii*	Dicranaceae	Analgesic
27	*Oreasmartiana*	Dicranaceae	pain, haemostasis, wounds, epilepsy, menorrhagia, neurasthenia
28	*Ditrichum pallidum*	Ditrichaceae	Convulsions, particularly in infants
29	*Entodonflavescens*	Entodontaceae	Earache, cold
30	*Fissidensnobilis*	Fissidentaceae	Hair growth and diuretic
31	*Funaria hygrometrica*	Funariaceae	haemostasis, pulmonary tuberculosis, bruises, skin infection
32	*Fontinalis antipyretica.*	Fontinalaceae	Fever
33	*Taxiphyllumtaxirameum*	Hypnaceae	Used for external wounds, haemostasis
34	*Aerobryumlanosum*	Meteoriaceae	burns
35	*Mnium cuspidatum.*	Mniaceae	Haemostasis, nose bleeding
36	*Plagiomnium acutum*	Mniaceae	Anti-infective and swellings
37	*Octoblepharum albidum*	Octoblepharaceae	Used as febrifuge and anodyne
38	*Dawsonia superba*	Polytrichaceae	diuretics, hair tonic
39	*Polytrichum commune*	Polytrichaceae	Haemostasis, wound healing, antipyretic, antidote, kidney and gall bladder stones, improve labour
40	*Polytrichum juniperinum*	Polytrichaceae	Prostate, urinary difficulties and skin disease
41	*Pogonatum macrophyllum*	Polytrichaceae	Inflammation and fever, diuretic, laxative and haemostatic
42	*Barbula unguiculata*	Pottiaceae	Fever and body aches
43	*Barbula indica*	Pottiaceae	Menstrual pain and intermittent fever
44	*Hyophilaattenuata*	Pottiaceae	cold, cough and neck pain
45	*Wei-siaviridula*	Pottiaceae	cold and fever
46	*Sphagnum sericeum*	Sphagnaceae	wounds skin infections, insects' bites, haemorrhoids and to treat eye diseases
47	*Sphagnum teres*	Sphagnaceae	eye diseases
48	*Haplocladiummicrophyllum*	Thuidiaceae	Cystisis, bronchitis, tonsillitis, pneumonia and fever
Hornworts			
49	*Ceratophyllum demersum L.*	Ceratophyllaceae	Purgative, astringent, constipation, antipyretic

7. Wound healing:

Kumar et al. reported that *Plagiochasma appendiculatum* use by the people of Gaddi tribe of Himachal Pradesh India, for the treatment of cuts, wounds and burns

8. Antihypertensive:

Rhodobryum giganteum (Schwaegr) Par. Contain p-Hydroxy cinnamic Acid, 7-8- Dihydroxy coumarin and helpful for treat cardiovascular problem and shows antihypertensive action.[13,14]

Results

Bryophytes may contain natural pesticides. In fact, the liverwort *Plagiochila* contains the sesquiterpene hemiacetyl plagiochiline A, a poison extremely potent in mice and it inhibits the feeding go an African army worm. The exploration of antiherbivory compounds in bryophytes could prove quite profitable. Funding and the resources of research institutions are generally directed to studies that have a likelihood of yielding financial rewards. Bryophytes are neglected largely because they have little direct commercial significance. However, peat is an exception, and has been exploited commercially for more than 150 years both as a fuel source and as a soil additive. The use of peat for fuel has increased in many countries, and it is now cheaper to exploit homegrown peat than to import other expensive raw fuel material. Ireland is a prime example of this, where peatlands have been exploited on a large scale and peatland habitat has been dramatically reduced in area. Because of the water-retentive properties of *Sphagnum* moss (a principal component of peat, holding up to 20 times its own weight, peat is also highly valued as a soil conditioner and a plant-growing medium.[15,16]

Sphagnum moss has been used as an effective filtering and absorption agent for the treatment of waste water and effluents from factories with acid and toxic discharges containing heavy metals, organic substances such as oils, detergents, and dyes and microorganisms. Peat can also be used as an absorbing agent for oil spills and as a filtering agent for oily waste water in vegetable oil factories. Because *Sphagnum* is soft in texture it is useful as a packing material when shipping products such as fresh vegetables and flowers. Other, more minor but relatively well documented, uses of bryophytes include the use of *Sphagnum* in babies´ nappies (because of its absorptive properties), hair-moss (*Polytrichum*) in home-made besoms, moss as a stuffing in pillows, and moss as decoration, particularly in the ceremonial costumes of indigenous peoples.

Mosses are also often used as a topdressing for flowerpots to prevent desiccation of the underlying soil. In the Philippines, eggs in crocodile farms are placed in an incubator covered with *Sphagnum* moss as it is believed that peat moss is an effective material in ensuring that the eggs remain at the required temperature. Potentially more important is the use of bryophytes in medicine. North American Indians have used various bryophytes as herbal medicines , and the Chinese still use some species for the treatment of cardiovascular diseases, boils, eczema, cuts, bites, wounds, and burns. Chemical analysis has revealed that most bryophytes, including *Sphagnum*, have antibiotic properties. Extracts of many species of mosses and liverworts contain phenolic compounds that inhibit growth of pathogenic fungi and bacteria. Dried *Sphagnum* is, therefore, an excellent surgical dressing because of its absorptive qualities (absorbing more liquid than cotton pads and its ability to prevent infection. Because of these properties, it was used extensively during World War I.[17,18]

Many moss species were reported to possess unique natural products or secondary metabolites such as phenols, flavonoids, alkaloids, terpenoids and other aromatic compounds with therapeutic potentialities. Historically, the therapeutic features of herbals are the concept of doctrine of signatures. Bryophytes form the basement of Chinese medicinal treatment. For example, liverwort was used to cure hepatic disorders, *Polytrichum commune* induce women's hair growth. Gaddi tribes of Himachal Pradesh, [29] used *Plagiochasma appendiculatum* for treating skin diseases, *Targionia hypophylla* used by Irular tribec of Attappady to cure skin diseases due to resembles of thallus to the warty surface of the diseased region and *Frullania ericoides,* liverwort for hair-related applications by tribal people of South India. Species like *Sphagnum*, *Barbula*, *Bryum*, *Octeblepharum* and *Fontinalis* are used to treat different diseases, including cardiovascular diseases, inflammation, fever, lung diseases, infections, wounds and skin prone diseases. The aqueous extract of the three mosses like *Brachythecium rutabulum, Calliergonella cuspidate* and *Hypnum mammillatum* showed potent antioxidant activity. The species like *Polytrichum commune* were used as antipyretic and anti-inflammatory agent and boiled with tea for treating the cold. *Rhodobryum giganteum* is another species traditionally used to treat diseases like cardiovascular diseases or angina.

The moss *Plagiochilla beddomei* possesses significant antioxidant activity. The moss *Physcomitrella patens* under axenic condition produces a tetracyclic diterpene, namely 16α–hydroxykaurane (16α-hydroxy-ent-kaurane, Kaurenol, $C_{20}H_{34}O$.[1] α and β pinineallomadendrine from *Plagiochilla stevensoniana* were useful as anticancer and antimicrobial compounds. Mosses retard the growth of cancer cells in *in vitro* culture studies. The plant derived natural products occupy an important place in the area of cancer chemotherapy because of minimal side effects. *Polytrichum commune* plays significant role especially for the therapy of lymphocytic leukemia. [19,20]

Phenolic compounds isolated from *Atrichum*, *Dicranum*, *Mnium*, *Polytrichum* and *Sphagnum* spp. were reported to possess antimicrobial properties. The antimicrobial activity for three moss species *Eurhynchium angustirete*, *Rhytidia delphussquarrosus* and *Rhodo bryumroseum* was validated by Nikolajeva. *Thuidium gratum, Ectropothecium aeruginosum, Sematophyllum caespitosum*, *Stereophyllum radiculosum, Babulalam berenensis, Campilopusa spericuspis* and *Calympereserosumlam berenensis, Campilopusa spericuspis* and *Calympereserosum* were proved for their potential antimicrobial properties. The moss *Atricum undulatum* possesses strong antifungal activity against *Aspergillus versicolor* and *A. fumigatus.*[21,22]

Conclusions

In ancient times bryophytes have been used as herbal medicines in various parts of the world. Dioscorides ascribed medicinal properties to *Marchantia polymorpha*. During the middle ages, the large thallose liverworts Mere interpreted according to the Doctrine of Signatures. The decoction of liverworts was supposed to be effective in the treatment of disorders of liver, and that of the "hairy-cap moss" to beautify ladiks hairs.[27,28] In Northem Montana

(USA) *Polytrichum juniperinum* is still used for preparing various medicines. In Kumaon region (North-Westem Himalayas) liverworts *Marchantia polymorpha* and *M. palmata* are used as medicine for boils and abscesses, whereas mosses are used in the preparation of an ointment for cuts, bums and wounds. In China, more than 30 species of bryophytes have been recognised as curative agents. Clinical researches are also being carried out to confinn the effectiveness of these medicines and it has been observed that the extract of moss *Rhodobryum giganteum*, which is used to cure angina (an attack of intense constricting pain), increased the rate of flow in aorta of white mice by over 30% causing a reduction in the amount of oxygen resistance. Modem phytochemists and biochemists have isolated a vast number of biologically active organic compounds from bryophytes which are of potential use in pharmaceutical industry. It has been demonstrated that certain products of bryophytes inhibit the growth of microorganisms. Three prenylbibenzyls from *Radula* spp. inhibit the growth of *Staphylococcus aureus*. Many species of bryophytes have been shown to possess antitumor activity. The first antitumor active compound, diplophylline, was obtained from liverworts. This compound shows significant activity against human carcinoma. Antitumor sesqueterpenoids have also been isolated from many liverworts[23,24:

Antitumor Sesqueterpenoids Isolated from Bryophytes.

Diplophyllin…. *Diplophyllum albicans, D. taxifolium*

Marchantin A…..*Marchantia polymorpha, M. tosana, M. palacea*

Riccardin…… *Riccardia mulrijida*

Perrottetin E ……*Radula perrottetii*

Pagiochiline A …….*Plagiochila* sp.

Pinguinsane…….*Trocholejeunea sandvicensis*

Bryophytes also show activity against some plant pathogens. Extract of the liverwort - *Herbertus aduncus* inhibits the growth of some plant pathogenic fungi. Many species of mosses (e.g. *Dicranum scoparium* ie. *D. japonicum*) contain some rare fatty acids which completely inhibit the growth of the fungus causing rice blast, *Pyricularia oryzae* [25,26]

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